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Some Scientific Aspects of Packaging and Quick-Freezing Perishable Flesh Products

II—Packaging Flesh Products for Quick-Freezing[1]

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BECAUSE many flesh products are decidedly seasonable, and because it will be desirable to package such products largely during times of oversupply, the finished product should be capable of prolonged cold storage at or near the point of manufacture. Therefore, let us consider some of the principal sources of trouble during storage.

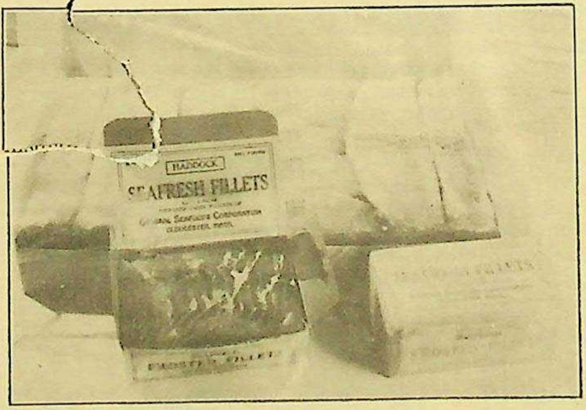

Figure 1—One-Pound Carton Containing Three Portion-Size Haddock Fillets, and Separately Wrapped Haddock Fillets Assembled into a 10-Pound Carton

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[1] Received April 15, 1929.

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Causes of Deterioration

Desiccation is one important cause of deterioration and is due largely to the lack of constancy and uniformity of temperatures throughout the storage room. Heat penetrates into the room through the walls and open doors and is given off by lights and by the bodies of workmen; and this heat is absorbed by the refrigeration pipes. The stored product is of course warmer than the pipes and the saturation point of the air is lower at the pipes than at the product. Thus moisture is continuously absorbed from the product, carried by convection currents to the refrigeration pipes, and deposited there in the form of frost. Obviously this moisture evaporation from the fish is more or less in direct proportion to the surface area exposed. The extent of this evaporation may be seen from Table I.

The experiments reported in Table I were carried out with unglazed fish under European storage conditions, at a temperature of −7° C. and 85 to 90 per cent humidity. Peterson[2] says that in Europe fish are usually frozen suspended individually in air at from −15° to −7° C., more often at the higher temperature. In the United States, however, only approximately 25 to 40 per cent are frozen individually, the remainder being frozen in blocks; and sharp-freezer temperatures are very low—from −23° to −34° C. For these and other reasons, the desiccation shown in Table I is very much greater than is usual under the United States practice of sharp-freezing and cold-storing whole fish.

As will be noted from the table, the factors of size, shape, and leanness or fatness control the rate of evaporation to a certain extent. A small fish dries faster than a large one of the same species. Lean fish dry faster than those protected by a subcutaneous layer of fat. Yet the eel, which is fattier than the mackerel, dries faster during the first stage, because of the larger ratio of surface to bulk. Since these figures are according to European technic, they are slightly higher than will be the case in our domestic freezers, but they illustrate the great necessity for protection against evaporation during storage.

Table I—Loss in Weight during Freezing and Cold Storage of Whole Fish[a]

Kind of Fish	Initial Weight	Number of Days Stored							
		10	20	40	60	80	100	120	140
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
Coalfish	3827	5.9	8.9	15.0	21.0	..	..	..	..
Cod	2674	7.4	11.0	18.2	25.5	..	..	..	..
Haddock	858	11.4	18.2	28.6	37.3	43.0	..	..	..
Haddock	318	17.0	27.6	42.7	52.0	57.5	60.0	61.6	62.3
Plaice	570	9.6	16.6	28.1	37.2	44.8	..	..	..
Plaice	179	15.1	26.2	43.3	54.2	62.0	65.0	65.5	66.5
Mackerel	421	3.3	7.8	14.9	19.9	24.2	27.2	29.4	31.1
Eel	349	8.3	12.3	17.7	20.9	22.6	..	..	..

[a] Zentral-Einkaufsgesellschaft m. b. H. Berlin, 1916.

Oxidation is another prolific source of trouble, for the fats of most flesh products are readily oxidized by contact with the air during cold storage. The rate of oxidation decreases with the temperature of the storage room, and increases as the fat-containing tissues are broken down by autolysis. It is most rapid on exposed cut surfaces, and may best be held in check by a practically air-tight protective coating and low storage-room temperatures.

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[2] Peterson, *Refrigerating World*, September, 1924.

The natural bright color ("bloom") of flesh is often changed during prolonged cold storage to a brownish tinge. This is caused by conversion of the hemoglobin of the product to methemoglobin through contact with the gases of the air.[3] Discoloration, like oxidation, is most pronounced in exposed surface areas.

Flavor is another quality which may suffer during prolonged storage and subsequent distribution. This is due, among other causes, to desiccation, evaporation of volatile substances, oxidation of fats, and absorption of odors from contaminated storage rooms, refrigerated freight cars, and dealers' ice boxes. All these factors are minimized by reducing the exposed surface area and utilizing an air-tight protective coating.

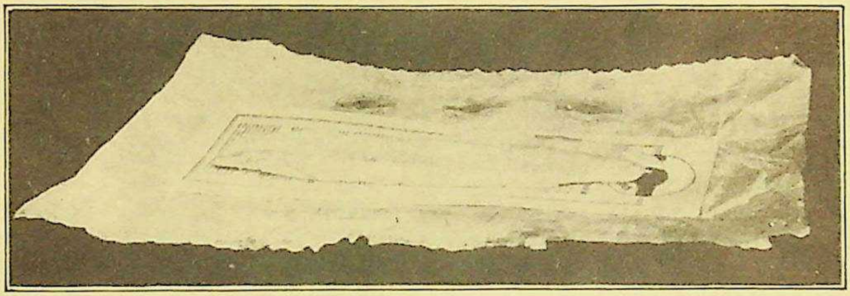

Figure 2—Individually Frozen and Wrapped Haddock Fillet

Heat leakage into a cold-storage room, refrigerated car, or insulated shipping container is in direct proportion to the surface exposed; and the amount of heat which the product can absorb without thawing is dependent upon the quantity of the product. The greatest care must be taken to prevent thawing of carloads of quick-frozen products during transfer from one storage point to another, for if the product is allowed to soften it will be slow-frozen when it again enters storage. Therefore, it is essential that the product be packed as compactly as possible.

Bacterial contamination of flesh products is difficult to control, and it is obviously desirable that the products be protectively packaged as soon as possible after having been dressed.

Manufacturing and Marketing Requirements

The requirements of the manufacturer, distributor, and consumer must be met satisfactorily if quick-frozen, packaged, perishable flesh products are to become a commercial success. From the manufacturer's viewpoint the product must be packed so as to facilitate quick-freezing and in such a manner as to require the minimum of wrapping and cartoning material for a given weight of product. Economical shipment from manufacturer to dealer requires that the individual packages be packed in strong, dry, inexpensive, non-returnable, heat-insulated shipping containers, which must be rectangular and packed solidly full.

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[3] Taylor, "Refrigeration of Fish," Appendix VIII to report U. S. of Commissioner of Fisheries for 1926, p. 523.

The retail dealer will insist that the individual packages themselves be clean, dry, and odorless; retain their attractive appearance after being thawed; and require the minimum weighing and wrapping before delivery.

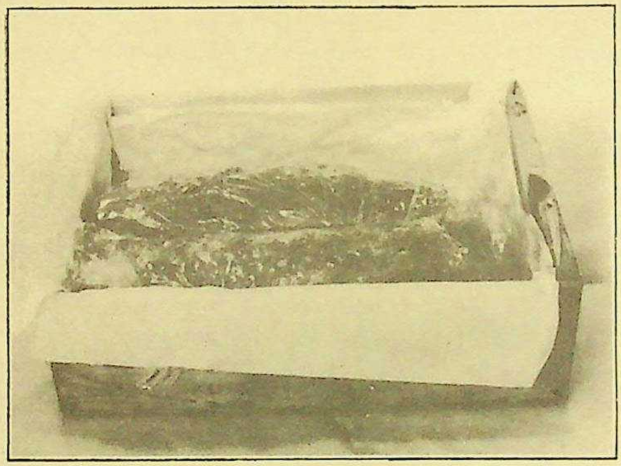

Figure 3—Individually Frozen Salmon Fillets

Most important of all, perhaps, are the demands of the ultimate consumer. First among these must be uniform high quality—the goods must be packaged at or near the point of production and must have the flavor, juiciness, color, and appearance characteristic of the best unfrozen materials. They must be absolutely clean to start with, sanitarily handled throughout the production process, and effectively protected from contamination until they reach the consumer's kitchen. They must keep fresh the maximum time after thawing, and be free from inedible portions, ready to cook the moment they are taken from the package, of convenient size, and trade-marked in such a manner that the brand carries through to the consumer's kitchen.

Packaging before and after Freezing

It will have become apparent from the foregoing that a successful package of quick-frozen flesh products must be completely full, with the minimum amount of air within the package. This can be accomplished only by packing the product first and freezing it afterward. Unfrozen flesh products—even those containing a considerable proportion of large bones—are comparatively soft and yielding, and the individual cuts can be made to fit together so as to fill compactly the carton in which they are packed. After such products are frozen, however, they are unyielding and usually of irregular shape, and therefore cannot be compactly assembled into a package. These facts are well illustrated in Table II.

Table II—Space Occupied by Certain Frozen Foods

PRODUCT	VOLUME OCCUPIED BY ONE POUND		
	Unfrozen	Packaged and then frozen	Frozen and then packaged
	Cubic inches	*Cubic inches*	*Cubic inches*
Haddock fillets	26 to 27	29 to 30	54 to 90
Salmon fillets	26 to 27	29 to 30	64 to 70
Codfish steaks	26 to 27	30 to 31	51 to 55
Shelled oysters	27 to 28	29 to 30	56 to 59
Sea scallops	26 to 27	29 to 30	57 to 59
Lamb kidneys	26 to 27	28 to 29	38 to 43
Lamb chops	26 to 28	30 to 31	44 to 48
Sirloin steaks	26 to 28	29 to 30	45 to 47

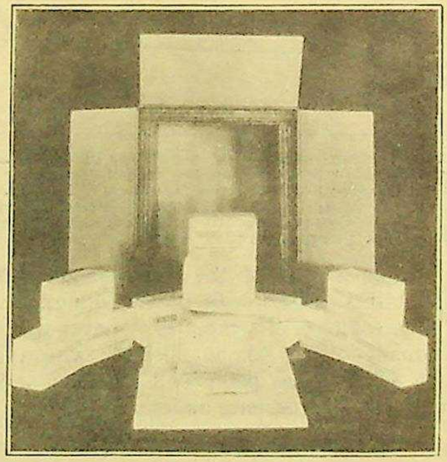

Figure 4—Insulated Container for Shipping

It is significant that a carton of product packed before it is frozen usually exposes very much less surface area than the same weight of that product frozen before it is packaged. Thus, in a one-pound package of haddock fillets, 1⅞ × 3 × 5 inches (Figure 1), composed of three portion-size pieces of fillet fitting snugly against each other and completely filling the package, the surface exposed to desiccation and oxidation amounts to only 60 square inches—i. e., to the area of the ends, sides, top, and bottom of the package.

Two half-pound haddock fillets laid out flat and frozen individually present approximately 177 square inches of surface area. These same two half-pound haddock fillets separately wrapped and then assembled into a ten-pound container before being frozen will have a total surface area of 106 square inches—and in actual practice only about an average of 25 per cent of this area would be exposed at the surface of the block of product within the carton.

A moisture-vapor-proof and air-tight covering has been shown to be another essential feature of packaged quick-frozen flesh products. This is an additional reason why the products should be packaged before being frozen, because both the necessity for and the cost of wrapping increases with the amount of surface which must be protected. The 14-ounce individually frozen haddock fillet shown in Figure 2, placed on a sheet of cardboard and then wrapped in parchment paper, required 280 square inches of wrapping material; while a fillet of the same weight individually wrapped and then packed with others in a carton required only 127 square inches of wrapping to cover it completely. The individually frozen salmon fillets shown in Figure 3 occupied 66 cubic inches per pound of fillets, and required 188 square inches of wrapping material.

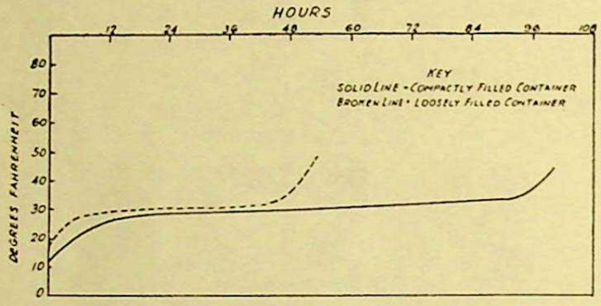

Figure 5—Temperature Rise in Centers of Two Identical Corrugated Shipping Containers, One Compactly Filled with Two Ten-Pound Cartons of Haddock Fillets Packaged before Being Frozen and the Other Loosely Filled with Single Fillets Frozen Separately before Being Packed. Average Room Temperature, 60° F.

Kinds of Packaging Materials

Now let us consider the relative merits of various wrapping and cartoning materials available for use in packaging quick-frozen flesh products. The first material to be used extensively for this purpose was pure vegetable parchment paper, paraffin-coated on both sides. This is a thoroughly excellent wrapping material, one of its most valuable characteristics being that it will not disintegrate in the presence of water—it can, in fact, be boiled for a prolonged period without becoming weakened. Ordinary transparent cellulose sheets—e. g., Cellophane and Crystal Klear—have been used for wrapping flesh products and have the benefit of displaying the products to excellent advantage. This class of material has, however, proved unsatisfactory, chiefly because it is not moisture-vapor-proof, and the sheets adhere tightly to each other both while the product is frozen and after it has thawed.

Compact cardboards containing a minimum of air spaces and cold-waxed on both sides, have been extensively used for cartoning quick-frozen flesh products and have proved very satisfactory. It is probable that the inclusion of a thin asphalt layer in the center of the board considerably increases its vapor-proof value.

Glassine paper, paraffin-coated on both sides, is being successfully used as a heat-sealed wrapping for the outside of small cartons. This material has a relatively high resistance to the passage of moisture vapor and is fairly transparent. However, it loses strength when kept wet for a prolonged period and is therefore not suitable for use in direct contact with a product.

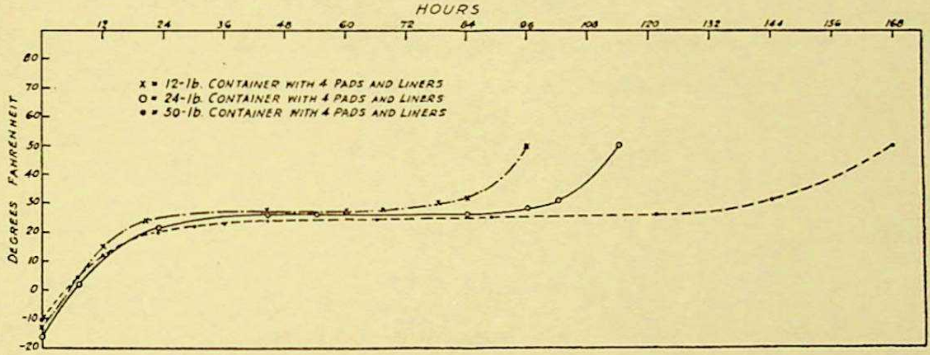

Figure 6—Temperature Rise in Center of Corrugated Shipping Containers, Filled with One-Pound Cartons of Frozen Haddock Packed before Being Frozen. Average Outside Temperature, 65° F. Container Similar to That Shown in Figure 4

Probably the most nearly moisture-vapor-proof and airtight wrapping available is an improved cellulose material known as Moistureproof Cellophane. This material is almost completely transparent and has a very high resistance to the passage of moisture vapor and other gases. The individual sheets do not stick together and the material is in itself water-tight and greaseproof. It is, however, more expensive than other wrapping materials, and its field of usefulness is limited by that fact. The relative moisture-vapor-proofness of some of the above materials was determined as follows:

> The paper to be tested is sealed tightly over the top of a glass crystallizing dish. One edge is then broken just enough to allow the insertion of a pipet. About 10 or 15 cc. of water are placed in the dish, after which the broken edge is tightly sealed again. These dishes are placed in the constant temperature oven, which is regulated to within 0.5° C. and in which calcium

chloride or concentrated sulfuric acid is distributed so that the atmosphere in which the dishes are exposed represents a practically zero relative humidity. The atmosphere inside of the dish, of course, represents 100 per cent relative humidity. The air in the oven or the desiccator is constantly agitated by a small fan connected to a small motor. The covered dishes are weighed to an accuracy of 1 mg. before the test and then placed in the constant-temperature oven for 24 hours. They are then removed, brought to room temperature and again weighed. The loss in weight is calculated back to the grams of water vapor lost per square meter of surface exposed per 24 hours, at 38.33° C.

The results are shown in Table III. Although no tests have been conducted at temperatures of less than 10° C., there is excellent reason to believe that the moisture-vaporproof qualities of Moistureproof Cellophane improve as the temperature is lowered to that at which frozen flesh products should be cold-stored; while the general tendency of waxed papers seems to be toward becoming relatively less vaporproof at very low temperatures—probably because at low temperatures the paraffin tends to contract or crystallize, thereby less completely covering the paper.

Table III—Relative Moisture-Vapor-Proofness of Several Wrapping Materials[a]

SAMPLE	WRAPPING MATERIAL	MOISTURE-VAPOR-PROOFNESS
1	Regular Cellophane	1920
2	Parchment, lightly waxed one side	1350
3	Glassine, unwaxed	1250
4	Parchment, unwaxed	1130
5	White glassine, waxed both sides	384
6	White waxed paper, waxed both sides	220
7	Brown waxed paper, waxed both sides	100
8	Glassine, waxed both sides	70
9	Kraft, waxed both sides	42
10	Glassine, waxed both sides	36
11	Kraft, waxed both sides	35
12	Glassine, waxed both sides	17
13	White waxed paper, waxed both sides	17
14	Kraft, waxed both sides	12
15	Moistureproof Cellophane	5

[a] These papers were taken from a variety of packages most of which contained bread or other bakers' products. The list includes some of the poorer grades of paper, some of the average grades, and three of the very best of the hundreds which were tested.

Insulated Shipping Cases

For commercial reasons it is desirable that inexpensive non-returnable insulated shipping cases be used in distributing quick-frozen packaged products. This precludes containers from such materials as cork board, balsa wood, and the various proprietary insulating materials.

Corrugated fiber board has been found to be a very satisfactory material from which to manufacture insulated shipping containers, and considerable quantities are now being used for that purpose. It has approximately the same heat-insulating value as cork board or balsa wood, is light, strong, and inexpensive. Fiber board may be made with either straw or chip corrugations, and with kraft, jute, chip, or straw liners. It has approximately the same heat-insulating value no matter from which materials it is made.

Although the construction and thickness of the corrugated containers used by different producers of quick-frozen products vary greatly, an excellent container may be made by placing four pads or liners within an ordinary slotted carton of the proper dimensions (Figure 4). The container should be as nearly cubical as possible, so as to expose the minimum surface to heat penetration: and, when possible, the corrugations in the liners should run horizontally so as to lessen convection currents. Obviously, the shipping container should be packed solidly full, because the heat leakage into the container is approximately in proportion to its surface area, whereas the amount of heat which can be absorbed by the product with a given temperature rise is in proportion to the volume of product (Figure 5).

Figure 6 indicates the effectiveness of corrugated fiberboard cases in protecting their contents from outside heat. It will be noted that the contents of the 50-pound container required 7 days to reach a temperature of 50° F., at which time the fish was still perfectly fresh.